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Ito, Kensuke and O'Dair, Marcus (2019) A critical examination of the application of blockchain technology for intellectual property management. In: Business Transformation through Blockchain: Volume II. Treiblmaier, Horst and Beck, Roman, eds. Palgrave, pp. 317-335. ISBN 9783319990576, e-ISBN 9783319990583. [Book Section]  
(doi:10.1007/978-3-319-99058-3\_12)

Final accepted version (with author's formatting)

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# **A CRITICAL EXAMINATION OF THE APPLICATION OF BLOCKCHAIN TECHNOLOGY TO INTELLECTUAL PROPERTY MANAGEMENT**

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This chapter critically investigates the application of blockchain technology for intellectual property management. To date, there have been relatively few critical discussions of the feasibility of utilising blockchain technology for the management of intellectual property, although much has been written, in media and industry sources, about the potential. Our aim, by contrast, is to examine possible limitations - and, subsequently, to suggest tentative solutions to the limitations we identify. Specifically, this paper aims to examine the use of blockchain technology for intellectual property management from two perspectives: operation and implementation. We conclude that, while commentators often focus on technical characteristics of blockchain technology itself, it is the incentive design – which was fundamental to the original Bitcoin proposal – that is also critical to truly decentralised, and disintermediated, intellectual property management.

## **Keywords:**

**Blockchain, Intellectual Property, Digital Rights Management, Copyright,** Incentive Design, Authenticity, Critique, Provenance, Disintermediation, Decentralisation, DApps, Distributed Ledger Technology, Music Industry, Proof of Existence.

## **Introduction**

Below, we set out the major challenges related to managing intellectual property in the digital era, before going on to examine ways in which supporters have suggested that blockchain and distributed ledger technologies could contribute to solving these challenges. Key technical terms are also explained.

*Intellectual property management in the digital era*

‘Intellectual property’ (IP) refers to the protection of the application of ideas and information of commercial value (Cornish et al 2013, p. 6). Cornish et al (2013, p. 7) identify three central types of IP: ‘patents for inventions, copyright for literary and artistic works and associated products, and trademarks and names for the goodwill attaching to marketing symbols’. This chapter focuses in particular on copyright: ‘a right given against the copying of defined types of cultural, informational and entertainment productions’ produced by authors, playwrights, composers, artists and film directors (Cornish et al 2013, p. 8). Copyright is conferred automatically to literary and artistic works but only when written down or recorded: critically, ‘it is the particular expression making up a work which is protected, rather than the idea behind it’ (Cornish et al 2013, 9).

While digital technology is far from the first challenge to copyright, it may prove the most significant, since ‘digitisation has made unauthorised access and distribution of copyrighted work easy and ordinary’ (Klein et al 2015, p. 3). Indeed, some scholars have suggested that IP, as currently understood, may not survive the current era (Cornish et al 2013, p. 11). As Cornish et al (2013) assert, IP is essentially negative: although there may be positive entitlements, IP rights are primarily an attempt to prevent particular activities, such as piracy. In practical terms, however, lawsuits and threats have achieved limited results (Klein et al 2015, p. 31), since peer-to-peer file-sharing sites, for instance, have proved difficult to shut down. Digital technology has stretched copyright ‘to breaking point’, resulting in ‘a gulf between copyright law and everyday practices’ (Klein et al 2015, p. 1). There are problems with royalty payments, which are slow, inefficient and opaque, and it is difficult to assess whether labels, publishers or collection societies are processing payments efficiently (O’Dair et al 2016).

### *The possible role of blockchain technology*

Some have suggested that a solution could lie in distributed ledger technologies (DLTs), such as blockchain technology. A ‘distributed ledger’ can be understood as a type of distributed database; its aim is to overcome the presence of malicious users or nodes (Hileman and Rauchs 2017, p. 11). A blockchain is a particular type of distributed ledger: one that is ‘composed of a chain of cryptographically linked “blocks” contained in batched transactions’ (Hileman and Rauchs 2017, p. 11).

For reasons of space, we do not include a detailed discussion of the technical aspects of distributed ledger technology in this chapter; such information is readily available elsewhere (Nakamoto 2008; Buterin 2014; Antonopoulos 2015; Swan 2015; Narayanan et al 2016). The pertinent point for this paper is that Bitcoin, proposed in 2008 and implemented the following year, was radical in its removal of third parties

(in that instance, banks). Crucially, this disintermediation was achieved not only through technology but also through a deep understanding of game theory and incentives. However, Bitcoin can be understood as simply the first innovation in this space. Gupta (2017, p. 2) identifies subsequent innovations, of which the first is ‘the realisation that the underlying technology that operated bitcoin [the cryptocurrency] could be separated from the currency and used for all kinds of other interorganisational cooperation’. With this innovation came the understanding that blockchain technology, which, if not quite immutable, is certainly extremely robust since it has no single point of failure, could be utilised for more than bitcoin transactions. With ‘metacoins’ came the notion that bitcoins could be augmented, its functionality extended; with ‘altcoins’ came entirely new cryptocurrencies, and new blockchains. The subsequent innovation identified by Gupta, closely linked to one of these new blockchains, is the ‘smart contract’, ‘embodied in a second-generation blockchain system called Ethereum, which built little computer programs directly into blockchain that allowed financial instruments, like loans or bonds, to be represented’, rather than only bitcoins (Gupta 2017, p. 2). A ‘smart contract’, then, is a self-executing computer programme that automatically performs a given function (Hileman and Rauchs 2017, p. 11). Smart contracts have enabled the emergence of DApps, or decentralised applications with backend code running on decentralised, peer-to-peer networks.

While it is the global prominence, and fluctuating value, of bitcoin that has media headlines, Morabito (2017, p. vii) suggests, we should understand blockchain as more than a financial technology or ‘fintech’ phenomenon; it is being deployed in a range of domains and across a number of industries. Blockchain technology, in other words, can be used to as a register of intellectual property. In essence, this works through the use of ‘hashes’. A ‘hash’ is a unique string of alphanumeric characters that represents a given content file; it can be understood as a kind of ‘digital fingerprint’ (Antonopoulos 2015, p. xx). Crucially, it is short enough to be included in a blockchain transaction; ‘via the hash, the original file content has essentially been encoded into the blockchain’ (Swan 2015, p. 39).

Proponents identify three advantages of blockchain technology for creating a distributed IP database (O’Dair and Beaven 2017). Firstly, they claim that it guarantees *authenticity*: metadata can be inextricably bound to the relevant data file, be it a song or a film. Secondly, proponents state that blockchain technology allows for *provenance*: usage and ownership can be recorded. Thirdly, champions of the blockchain state that it can facilitate the faster and more efficient payment of *royalties*, in some cases by removing trusted intermediaries and facilitating a direct-to-fan model. These advantages may seem compelling, and they are propounded by a number of start-ups, funded either by traditional venture capitalists or by means of token sales, also known as initial coin offerings or ICOs. A token sale can be

akin to a Kickstarter-style crowdfunding campaign, which allows the general public to participate in an early-stage project; the important difference, however, is that most tokens are tradeable (Chen 2017). Token sales offer the possibility of raising significant sums of money at speed: millions of dollars can be raised in seconds, even by companies yet to produce a product (Sahdev 2017). At the same time, it is important to recognise that token sales vary wildly, with only a minority of tokens offering fractional ownership in the value of the underlying organisation (Conley 2017, p. 1).

Having examined both the challenges of contemporary intellectual property management and the claims made for blockchain and distributed ledger technologies as a solution to these challenges, we now go on to critically examine limitations of the technology - first from an operational perspective, sub-divided into authenticity, provenance and royalty stability, and then from the perspective of implementation, sub-divided into files, metadata and licensing.

## **Review from an Operational Perspective**

This section covers potential problems of using blockchain technology for IP management from an operational perspective. Specifically, we here examine each use case in order, from simple to complex, and classify their limitations in terms of authenticity, provenance and royalty stability. Having identified a number of challenges, we then go on to suggest possible solutions which we could consider under a current environment.

### *Authenticity problem*

In almost all blockchain-based intellectual property management systems, we first have to convert some IP information into a hash and record it in a distributed ledger. This is a relatively simple task but it is valuable in providing assurance that a protected work existed at a certain point in time (Proof of Existence) because blockchains are robust - even 'immutable'.<sup>1</sup> By adding information on rights holders, it would be possible to go a step beyond proof of existence - to what we might call Proof of Ownership.<sup>2</sup> A number of related services have already been proposed, such as a digital certificate that makes use of blockchain 'timestamping' (e.g. Binded) and a common protocol for IP metadata (e.g. Coala IP, SPOOL on Ascribe). However, a fundamental problem in this first step is that, for information that is not native to the blockchain, we cannot guarantee its authenticity at the moment of registration: this is sometimes referred to as the 'garbage in, garbage out' problem. If copyright ownership information is entered incorrectly, either deliberately (by a bad actor) or mistakenly (due to human error), it is unclear how

conflicts would be resolved without a trusted third party (TTP). Although it can store information in a robust and immutable manner, blockchain technology alone cannot confirm the authenticity of the registered information.

Unless and until we can address this authenticity problem, practical operations will be restricted to a public but permissioned network that can contain only information authorised by a TTP. This corresponds to the example of the academic journal, Ledger (<http://ledgerjournal.org>), where the process of reviewing submitted papers is recorded on a blockchain, rather than a centralised pre-print server. In this case, even though the data can be preserved in a secure environment, only the authorised editors are responsible for its input. If a solution requires governance by a TTP, it is not based on the innovation achieved by Bitcoin, and it also contradicts our goal of facilitating IP management by disintermediation.

### *Provenance problem*

If, for the sake of argument, we assume the authenticity problem is somehow solved, the next challenge concerns recording transfers of ownership. There is an expectation that blockchain can facilitate the transfer of IP without requiring a TTP, and that it can overcome the problem of ‘piracy’ through issuing a digital certificate or a secret key to access digital contents (e.g. Ascribe, CopyrightBank). Here, however, we face another problem related to provenance: blockchain cannot prevent ‘double-spending’ and unauthorised replication outside the network (O’Dwyer 2017, p. 306). Physical assets such as paintings, for example, can easily be transferred between owners without updating the information stored in a ledger; moreover, even digital assets are replicable for a temporal owner who has the private key. Needless to say, once IP is transferred outside the network, records in the ledger no longer provide a reliable certificate of ownership.

Until this provenance problem is solved, practical operations will be restricted to issuing transferable ownership certificates, where the rights to exclude unauthorised use depends not on blockchain but on the power of TTPs such as government representatives or collection societies. This corresponds to the example of the digital certificate (e.g. Ascribe) that embeds terms of service compliant with local laws in order to be used as evidence in court to resolve ownership disputes. As with authenticity, this solution would not contribute to the disintermediation and efficient IP management because it is costly to settle ownership disputes after the fact, by relying on a TTP, rather than preventing such problems beforehand by incentive design.

### *Royalty stability problem*

If we assume both the authenticity and the provenance problems are solved, then disintermediated IP management would finally become feasible. As stated above, a number of intermediaries currently exist to monitor the secondary use of intellectual property, as manifest in both physical and digital works, and their high management costs diminish royalty payments to creators. In order to improve such a situation, a variety of online platforms are being developed that aim to directly connect artist and consumer by using blockchain to store royalty payment records in addition to contents transaction. This is evident especially in the music industry, where monitoring costs are high (e.g. Ujo Music, Peertracks, Bittunes.)<sup>3</sup> However, one final challenge remains: we cannot use stable payment methods for decentralised royalty management. Although cryptocurrencies provided a new payment method that does not rely on a TTP, their price has thus far not been sufficiently stable as to use as a store of value. Instead, many cryptocurrencies are volatile in the extreme. It would be more practical for intellectual property management to use DApps,<sup>4</sup> for instance on Ethereum; specifically the DApp could circulate internal reward tokens associated with ownership transfer and thereby manage the transactions of both IP ownership and royalty payments on the same network. However, this would make the royalties paid to artists even more unstable, because there is fluctuation in the value of reward tokens within the DApp, as well as at the Ethereum network level.

As long as we cannot solve this royalty stability problem, practical operations will be restricted to a service whose royalty payment confronts the trade-off between efficiency and stability; we must accept significant price fluctuations in return for efficient payment with no intermediaries, or, conversely, must rely on costly intermediaries and legal currencies in return for stable royalty payments. Therefore, even if we could solve the problems of authenticity and provenance, the system needs to set an optimal boundary on to what extent royalty management should be decentralised in order to maximise royalty payments to creators.<sup>5</sup>

### *Tentative solutions*

We have thus far investigated several use cases concerning IP management by blockchain technology, and have discussed three cumulative obstacles: authenticity, provenance and royalty stability. The consistent challenge is that IP is not native to the blockchain, and can have an independent value even outside the network.<sup>6</sup> In the case of cryptocurrencies represented by Bitcoin, we can trace the precise history of transaction and issuance because the numbers recorded in the ledger serve as the only evidence

of asset value. In the case of intellectual property, by contrast, we face a number of challenges in keeping IP data consistent with the actual asset, because the value of the asset exists separately from the ledger. In other words, DLT can make the data robust and immutable, but only once it is correctly registered - and it cannot accurately validate the condition of external entities. IP management may, then, need a new technology or incentive design which addresses assets with independent value, rather than simply applying to IP management a system developed for cryptocurrencies. How, then, can we overcome these challenges? Below, we consider some tentative solutions for each challenge in turn.

As regards the *authenticity* problem, similar discussions have already been made in Oracle, a system that acquires information outside the blockchain network as a condition for executing smart contracts. If we consider the example of a prediction market, one of the most common applications of Oracle, users need to reach consensus on the outcome of predicted events (about weather, the stock market, sports matches and so on) in order to trigger payments. Thus, this shares the same challenge as intellectual property management: how to prove the input data are truly correct. While most of the implemented oracles adopt a centralised solution relying on a TTP (typically information providers), some propose a decentralised solution to the problem. For example, Peterson et al. (2018) describes a unique Oracle for Augur that delegates the outcome determination to some internal users or ‘reporters’. Reporters in this system are incentivised to act honestly by the mechanism that each reporter stakes tokens against an option they believe as most likely and then all staked tokens are redistributed to those reporters who chose the option consistent with consensus.<sup>7</sup> In addition, Brey (2017) deals with an attempt to design a decentralised reputation network formed through token-based incentives and to trade the reputation data in its own Oracle for Tru. These approaches, namely token staking and reputation systems, will also be useful in addressing the authenticity problem for IP management, by helping to achieve decentralised consensus.

The *provenance* problem could in part be solved by the fact that we have an incentive to maintain the chain of provenance to avoid decreasing the value of a given asset (De Filippi et al 2016, p. 5). Furthermore, the provenance problem could be addressed through tokenisation, a method that divides the value (or associated rights) of a work into tokens whose management can be internalised in the ledger. Unfortunately, effective tokenisation is currently limited to goods with a source of value that is traceable on the ledger or transferrable by tokens; the former corresponds to an example of online ticket (e.g. Aventus), while the latter corresponds to tokens issued in a creator’s name (e.g. Tokit on SingularDTV). In other words, even if an asset is tokenised under the status quo, this will not overcome the provenance problem without the existence of TTP, because IP can still be copied or double-assigned behind the token



holders' back. Nevertheless, tokenisation has a great potential to solve this problem, in two broad ways. In the first scenario, which we might call the internal method, the tokens denote IP rights; this method represents an attempt to make IP rights traceable, and could be successful as long as we can prove the connection of value between tokens and creative works<sup>8</sup>. The second scenario is the external use of tokens, in which tokens are a form of compensation, or reward, for creators of IP. This is an approach to mitigate the provenance problem by incentivising creators even when works are not protected by exclusive copyright; anyone can freely access and copy them. Externalisation therefore has a synergy with digital content which we can duplicate with almost no additional costs. For example, Everpedia, a kind of decentralised Wikipedia, already issues tokens to users who contribute by editing articles, and Steemit adopts a similar reward system towards blog posts and their evaluation.

Regarding the *royalty stability* problem, a straightforward but effective solution would be to adopt 'pegged cryptocurrencies', whose value is backed by stable assets. Tether, Nubit and BitUSD, for example, are examples of cryptocurrencies pegged to US dollars, and there is also a project to issue the tokens pegged with gold like DigixDAO. These attempts can bring both value stabilisation and efficiency to payment methods. In particular, the Dai Stablecoin System by MakerDAO is noteworthy in that it aims to stabilise token prices in a decentralised manner. The system uses two main protocols in order to achieve stabilisation without a TTP holding vast amounts of US Dollars in reserve: users have to deposit an appropriate amount of ether as collateral before issuing a token, and the amount is calculated based on the price of US Dollars acquired from the outside by the distributed Oracle. Since this token allows an integrated application to maintain the characteristics as DApps, the Dai Stablecoin System will be effective on the stable and disintermediated IP royalty management.

## **Review from an Implementation Perspective**

In this section, we investigate the methods and challenges of blockchain-based applications for IP from an implementation perspective. This is important because a system for efficient IP management generally requires the implementation of multiple service layers, each with a different method for decentralisation. For simplicity, we here divide the layers into three: files, metadata and licensing. We examine these three layers in turn, in each case analysing examples of existing services.

### *Files layer*

When implementing a system aiming for disintermediation of IP management, the most fundamental layer we can consider decentralising would be file storage: the layer that contains original digital content

such as music, movies and images. Before the emergence of blockchain technology, decentralisation of this layer can be understood as essentially an extension of the use of peer-to-peer file sharing systems for the high-speed transfer of large volume data. Resilio Sync (formerly BitTorrent Sync), for example, provided a system to synchronise files in local storage among multiple devices based on BitTorrent – one of the most popular peer-to-peer file transfer protocols. More recently, Benet (2014) extended this idea to a browser-based file system named IPFS (InterPlanetary File System) and proposed a web page that works even without a server. However, these systems themselves lack Bitcoin's unique incentive design – only more recently have they started to integrate token-based rewarding to promote the autonomous working of the distributed storage network. Nodes in these new systems all lend and borrow their storage space via tokens and store the hash values of segmented data as Merkle tree format along with the original data, but the methods are slightly different to prove without a TTP that the data are correctly stored.<sup>9</sup> For example, Storj is designed to reward the storage provider if he/she can return a hash value consistent with the regular requests by clients, and the Merkle tree of hashes is preserved in the Ethereum blockchain (Wilkinson et al. 2016).<sup>10</sup> In Sia, while the storage provider similarly obtains reward tokens when he/she successfully returns a valid hash list of a part of the stored data in predetermined frequency, the Merkle tree is preserved in its original proof-of-work blockchain (Vorick and Champine 2014). Furthermore, Filecoin, proposed for usage with IPFS, links storage proof and the influence over its original blockchain: a node can generate the next block with a higher probability if it is proved to store the client's data for a specified time (Protocol Labs 2017).

With these systems, creators will be able to store original IP data in an environment that is neither entirely self-contained nor dependent upon a TTP. On the other hand, we can point out two main problems with regard to decentralising the files layer. Firstly, the decentralisation of the files layer does not make a very significant contribution to the goal of efficient IP management through disintermediation. Most of the argument on inefficiency has been made against a number of intermediaries for the management of IP rights and royalties, not for the storage of original files. Considering that we also need additional costs (tokens) in order for the file storage to function autonomously, it would be more reasonable in many cases to use existing services relying on TTP such as cloud storage, rather than attempt to decentralise this layer.<sup>11</sup> Secondly, as far as the authors know, all peer-to-peer storage systems with Bitcoin-inspired incentive design (e.g. IPFS with Filecoin) are currently under development, so that there are no practical applications for IP management based on them. Although implementation plans have often been announced in the music industry, for instance, we are not aware at the time of writing this chapter of any projects that have successfully achieved decentralisation of the files layer.<sup>12</sup> The risks and benefits of using such new file storage systems, therefore, remain uncertain.

### *Metadata layer*

Many applications use the database management system (DBMS) for efficient data control. Unlike storage and file systems, such a database generally stores the structured metadata which correspond to the original data, and DBMS frees us from the programming task for stipulating data location and access authority. This convenient middleware is adopted for IP management as well – for example, the metadata of registration rights such as trademarks and patents are all published on the database by management authorities (e.g. EUIPO, EPO). Decentralisation of this layer has already been popular as distributed databases which were implemented for the main purpose of resolving the large-scale data management problems by making distributed processing easier and more efficient (Özsu and Valduriez 2011, p. 3). Blockchain technology is, as Hileman and Rauchs (2017, p. 11) stated, often referred to as distributed ledger technology (DLT) while being treated as a kind of distributed database. This is to emphasise several different aspects of blockchain, such that it is decentralised for robustness, rather than efficiency, and is proposed originally as a component of the peer-to-peer system that did not assume central management (Nakamoto 2008, Pinna and Ruttenberg 2016). It would be a natural approach to apply such blockchain-specific characteristics to existing distributed database management system (DDBMS). For example, BigchainDB aims to balance scalability and decentralized management through a hybrid method that the system uses DDBMS for both data storage and transaction recording,<sup>13</sup> while the communication between them requires the voting by the group of assigned nodes.<sup>14</sup> BigchainDB has especially a potential to have an influence on the future of IP management since it is being developed by many of the same individuals who developed Ascribe, a company dealing with digital certificates for IP ownership.<sup>15</sup>

The point we would like to make here is that existing distributed databases can achieve much of what can be achieved by blockchains. For example, as with other append-only databases, CouchDB can make data uneditable once inputted, while Apache Cassandra eliminates single points of failure from its network by peer-to-peer data management based on consistent hashing.<sup>16</sup> Considering that we can ensure something approaching immutability and a reasonable degree of robustness even in existing mechanisms, the new achievement by blockchain (in combination with proper incentive design) would be limited to the decentralised and autonomous management of the data recorded on the ledger by people with different interests. However, this has not yet been completely realised in a general-purpose DBMS. Even in BigchainDB, clients need to trust the nodes and the consortium as long as its consensus depends on the voting system. Other barriers to creating a decentralised autonomous management still remain too, such as the aforementioned authenticity problem and the Sybil attack problem, a risk typically faced by online

voting. Therefore, we need to be cautious in claiming blockchain technology can transform the metadata layer – not only in the case of IP management.

### *Licensing layer*

A significant proportion of the blockchain-based IP management applications we introduced in the previous section intend to record the transfer of the rights and values accompanying the registered contents. Such a layer for storing the history of status transition of the target files or metadata is referred here to as the licensing layer. A number of applications are being developed in this layer, because licensing is one of the most explicit extensions to the core concept of Bitcoin – a peer-to-peer transfer of the data stored in the ledger. In case of performing a simple Proof of Existence and certificate transfer, it would be sufficient to store the hash value corresponding to creative work in the Bitcoin blockchain (e.g. Ascribe, poex.io).<sup>17</sup> However, in order to execute wider and more flexible functions, including licensing and payment, we need to use blockchain as a platform which is able to develop DApps. In Ethereum, for instance, we can realise behaviors much more diverse and complicated than those required for a coin transaction by the following two sequential methods: creating a transaction to define and deploy a 'contract account' equivalent to an object in the context of programming, and sending another type of transaction containing the variables necessary for contract execution to the defined account (Buterin 2014, pp. 13-17). It should be emphasised that Ethereum blockchain does not hold the files or metadata; it recorded only the state transition of both user<sup>18</sup> and contract accounts. Accordingly, at least under the existing circumstances, a single blockchain cannot manage IP consistently from original file storage to license transfer.

The fact that a number of projects are being developed on the licensing layer suggests a confidence that implementation challenges can be overcome; certainly, the challenges are mild compared to those presented by the files and metadata layers. The real challenge in decentralising royalty management is to integrate licensing with these files and metadata layers - yet existing DApps focus on the licensing layer alone. In IP management, Ujo Music is an example of a platform attempting to address this issue: the company plans to decentralise multiple layers, including the licensing layer. In addition, needless to say, the problems from the operational perspective that we have discussed in the previous chapter still remain. Provenance and royalty stability are especially critical issues that should be dealt with through the design of the licensing layer, since we cannot solve them even if original files or metadata guarantee authenticity. Despite these challenges, licensing is the layer where application development is so active as to have a high possibility of making useful DApps for IP management ahead of other layers.

## Conclusion

The excitement surrounding the potential of blockchain technology for managing IP is understandable. Yet existing blockchain design, which is optimised for cryptocurrencies, should not and cannot be simply applied to the management of IP, since assets are not native to the blockchain. Significant operational challenges remain. As regards authenticity, we must address the ‘garbage in, garbage out’ problem. As regards provenance, we must consider our inability to prevent off-chain transfers. As regards royalty stability, finally, we must face the challenge of cryptocurrency volatility. Tentatively, we have suggested ways in which the various operational challenges might be overcome, for instance through the use of token-based incentives, and through pegging cryptocurrencies to fiat currencies. There are also, however, challenges from an implementation perspective - at the file, metadata and licensing layers. We are, as yet, not aware of use cases for the decentralisation of the file layer, so talk of using blockchains for managing actual files remains somewhat abstract. As regards metadata, the case for the use of blockchains as opposed to other forms of distributed database has yet to be made. As regards licensing, finally, we are not as yet aware of a single blockchain that can manage IP consistently from original file storage to license transfer.

It is also important to note that, even if we overcome the barriers to adoption identified in this chapter, not to mention additional concerns relating from the technical (scalability) to the legal and regulatory, the use of blockchains for IP management is not without risk: ‘smart contracts’ could replicate the worst aspects of digital rights management (De Filippi et al 2016, p. 3), while the censorship-resistance of distributed systems could make it very difficult to remove illegal content (O’Dair 2017, p. 22). Finally, not all commentators agree that the use of distributed ledgers for the management of IP necessarily results in a decentralisation of power in the interests of creators: for Zeilinger (2016), decentralised technologies will, on the contrary, simply reinforce models of centralised finance. Further examination of such risks is beyond the scope of this chapter, but the need for further research is clear.

The conclusion of our own research is that blockchain is a highly innovative technology that could transform the management of IP. A narrow focus on the technology itself, however, can result in a tech-utopian ‘solutionism’ that ignores significant challenges from both operational and implementation perspectives. The effective use of blockchain technology for IP management will be dependent upon the proper design of incentives, at both operational and implementation layers. The incentive structure, after

all, is precisely what was so innovative about Nakamoto's original proposal back in 2008. We should not forget that history.

## Endnotes

<sup>1</sup> More precisely, blockchain is pseudo-immutable because the accumulation of sequential blocks just makes tampering difficult (not impossible) through computational complexity, and we can rollback the stored record when blockchain is managed by a TTP.

<sup>2</sup> This extension has a novelty in that we can prove existence or ownership without disclosing the data on the contents by adopting a hash function.

<sup>3</sup> At the time of writing, the authors are not aware of platforms that have decentralised all three layers identified in the implementation section below.

<sup>4</sup> Decentralised applications: an app with the backend code running on a decentralised peer-to-peer network, rather than a centralised server.

<sup>5</sup> Note also that the realisation of decentralised payments needs additional fees as an incentive to the validators, such as transaction fees on Bitcoin and GAS on Ethereum. Thus, more precisely, we need to consider this cost as well as the price fluctuation risk in order for artist's royalty maximisation.

<sup>6</sup> We therefore can apply the three problems to other assets that have similar characteristics, such as real estate, jewellery and even supply chain management.

<sup>7</sup> See original paper for more details of the consensus including dispute round. Although it is not explicitly mentioned in the original paper, Augur's Oracle is often called as "distributed fact stream".

<sup>8</sup> Note that there are some projects trying to tokenise the external (non-native to the blockchain) assets by assuming a TTP responsible for custody of the assets (e.g. Latoken). Although this is partially contrary to the elimination of intermediaries, it will make a certain contribution to the provenance problem and the liquidity on the registered assets.

<sup>9</sup> Additionally, the approaches for redundancy (a design to handle the situation that a part of nodes is off-line) are also slightly different. See each whitepaper in detail.

<sup>10</sup> Storj changed its underlying blockchain from that of Bitcoin to that of Ethereum in 2017.

<sup>11</sup> It should also be noted that while the decentralisation of storage layer will reduce the risk of data loss, it does not solve the problems of authenticity and provenance.

<sup>12</sup> For example, Ujo Music is now using Amazon S3 while developers mentioned future implementation of decentralised (and autonomous) storage systems.

<sup>13</sup> The latter has a similar structure to blockchain.

<sup>14</sup> See McConaghy et al. (2016) for detail. Note that this whitepaper is no longer a living document according to the project members, and they are now writing a new updated version which is unavailable at the time the authors are writing this chapter (March 2018).

<sup>15</sup> McConaghy and Holtzman (2015), the whitepaper of ascribe, already mentioned the outline of BigchainDB.

<sup>16</sup> See Lakshman and Malik (2010) for detail.

<sup>17</sup> See Rosenfeld (2012) for further detail of this approach called ‘colored coin’.

<sup>18</sup> Defined as ‘externally owned account’ in Ethereum.

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